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Metrics for Mammographic Image Analysis Research

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The Digital Database for Screening Mammography (DDSM) is an infrastructure resource for use by the mammogram image analysis research community. It consists of digitized images for screening mammogram cases, associated information, and associated software tools. Portions of the DDSM resource are currently available on the world-wide-web and are already being accessed by researchers. This report dicusses the current state of the DDSM resource, problems encountered, and plans for completing the resource.

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K W Bauer   29 July '97
PI - Signature   Date

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4 Introduction

The Digital Database for Screening Mammography (DDSM) is an infrastructure resource for the mammographic image analysis research community. The purpose of the DDSM resource is to make it possible for researchers to conduct a more rigorous experimental comparison of the performance of different image analysis techniques. Previously, most research on computer image analysis for mammogram screening has used a "small" (10s to perhaps 100) number of images. Also, researchers have generally not been able to evaluate their work using the same images as used by other researchers. The DDSM infrastructure resource is meant to address these problems.

This annual report will (1) summarize the current state of the DDSM resource, (2) give some examples of problems that have been encountered, and (3) outline plans for completion of the DDSM resource.

5 Current State of the DDSM Resource

The DDSM resource currently contains both image-related data and associated software tools. The image-related data is organized by case, where a "case" is the standard four images of a screening exam, plus information on patient age, a radiologist-specified Bi-Rads breast density rating, a radiologist-specified outline of the suspicious region(s) in an image, and a radiologist-specified subtlety rating for detection of the lesion(s) in the image.

We currently have on-line for world-wide-web access one "volume" of normal cases, one "specialty volume" of cancer cases the present as masses, and another specialty volume of cancer cases that present as clustered microcalcifications. The normal cases were collected from the screening program at Massachusetts General Hospital specifically for the DDSM resource. The specialty volume of masses was collected from Bowman Gray Hospital prior to formally bringing them in as an additional subcontract on the DDSM project. The specialty volume of clustered microcalcifications is a data set used in publications by Nico Karssemeijer and is kept on-line for historical purposes as a service to the research community. In addition, we have another volume of normal cases which has been publicly announced and distributed but is not currently on-line. (In general, a "volume" is intended to be a data set of the size that just fits on one standard-format, 8-mm tape. This is for ease of exchanging data through the regular mail.)

In addition to the volumes that have been publicly announced, we have four more volumes of normal cases and two more volumes of cancer cases. We have completed the data accumulation and quality control checks on these additional volumes of normal cases, and they are ready to be made publicly available. One volume of cancer cases comes from the MGH mammography program and the other comes from the Bowman Gray mammography program. MGH is using a DBA film digitizer, and Bowman Gray is using a Lumisys film digitizer. We have digitized an optical density step wedge film on each digitizer, and will make available the measured pixel value to optical density conversion function for each digitizer. We are in the process of completing the accumulation and quality control checks on these two volumes of cancer cases, and should be done in the next few weeks. Once the quality control checks are completed on the two volumes of cancer cases, we will announce the availability of the six volumes of normals and two volumes of cancer cases. This is a total of approximately 500 normal cases and 100 cancer cases.

The software tools currently available on-line through the DDSM resource include a utility ("DDSMView") for viewing the images and image-related data, a routine for matching the results of a CAD detection program to the radiologist-specified ground-truth location of a lesion, and a pointer to a lossless JPEG image compression utility.

The DDSM resource is accessible through the world wide web URL:

`http://marathon.csee.usf.edu/Mammography/Database.html`

Each month, there are accesses to the DDSM resource from 25 to 30 distinct sites around the world, including a wide variety of academic, government and commercial sites in the US. A substantial fraction of these accesses each month appear to be from "new" sites, indicating that the user community is continuing to grow. In addition, we have been in correspondence with the organizers of the Fourth International Workshop on Digital Mammography about the workshop encouraging the use of the DDSM resource for the research results reported at the workshop.

To summarize the current state of the DDSM resource, we have approximately 600 cases of data available or ready to be made available, not including any "specialty" volumes. We have two clinical sites (MGH and Bowman Gray) regularly accumulating cases for the database, and are finalizing the details of bringing in a third clinical site.

6   Problems Encountered

The DDSM project has proved to be a great challenge, and we have encountered a number of problems that were not originally anticipated. One group of problems that was identified in last year's annual report revolves around the use of the DBA M2100 film digitizer purchased and installed at MGH. DBA was at first somewhat responsive in attempting to address the problems, and at the time of last year's annual report we were still hopeful that we would eventually have a fully functional DBA M21000 digitizer. However, since that time, DBA has declared their intention to end warranty support of the system. We have replied that, since the system has yet to fully function as originally represented to us prior to purchase, the warranty period should not have started yet. Our most recent letter to DBA concerning the problems with the digitizer concluded with the following:

> We repeat the request made of our letter dated January 23, 1997:
> "To make sure that we at MGH/USF are being fair-minded, and so we can calibrate our experience to the broader world of customers, can you give us the contact name and telephone number of persons who have one of the M2100 ImageClear Digitizer systems in regular use at 21 microns for upward of 32 films per day and are happy with it?"
>
> Lastly, we consider that the warranty period has not started yet, since MGH and USF and DBA Systems seem to agree that the product does not yet function as represented at the time of purchase. If your position is now that the system cannot feasibly be made to function as originally represented, then a simple statement to that effect may help to move our discussions forward.

This letter was sent in early March of 1997, and we have not yet had a response. Our speculation is that DBA has concluded that they cannot make the M21000 into a viable product, and that

they want to 'cut their losses' by ending support for the system at MGH. We are no longer hopeful that DBA is either interested in or technically capable of providing a fully functional M21000 digitizer.

We have been able to make some use of the DBA M2100 film digitizer by (1) using it as a 42 micron digitizer rather than a 21 micron digitizer, which seems to reduce the frequency of some of the problems encountered with the system, and (2) adding manual quality control steps to detect digitization problems which occur but are not detected by the system. Among the problems which occur when using the DBA M2100 digitizer and are not detected by the system are:

- Excessive "speckles" distributed throughout the image.
  This problem is recognizable as tiny bright spots randomly distributed throughout the image, including the background region. It is considered a serious problem for our application because these artifact bright spots may be confused with microcalcifications. We see this problem begin to happen as the illuminator bulb ages, but before the system calibration routine detects any problem. The problem goes away when an old bulb is replaced with a new one. An example of an image exhibiting this problem appears as Figure 1. Even with the reduced quality of reproducing a version of the digitized image as a reduced-resolution postscript file, the speckling artifact is quite evident.

- "Stretching" of an image.
  This problem is recognizable as a non-natural "stretching" of the image along the axis representing the direction of film travel through the digitizer. Our speculation is that this problem represents some intermittent failure in the film feed mechanism. When the problem is detected through manual review of the images after digitization, the digitization of the film is repeated. Generally the problem will not appear again on the second digitization. An example of an image exhibiting this problem appears as Figure 2. The problem is quite evident in the lettering in the upper right corner of the image.

- "Banding" of an image.
  This problem is recognizable as a "banding" which runs along the axis representing the direction of film travel through the digitizer. Our speculation is that this problem represents some combination of illuminator and calibration routine error. The problem generally goes away after replacing the bulb and re-running the calibration routine. An example of an image exhibiting this problem appears as Figure 3. The problem is especially apparent on the left side of the image.

Problems such as these are checked for by manual review of the images both at MGH and at USF prior to final accumulation into the database. The introduction of these manual quality control steps has slowed the pace of data accumulation relative to what we had originally anticipated.

Beyond the problems with the DBA digitizer, other unanticipated problems include:

- The unavailability rate of cancer case films.
  Whenever cases are requested from the film library, there is some unavailability rate rate due to files being mis-placed, incomplete, or in use for some other purpose. Our experience is that this rate is substantially higher for cancer cases than for normal cases.

- The permanent marking of cancer case films.
  We have found that some films from older cancer cases have markings on them which are not readily removed. The markings were apparently made in something other than the typical grease pencil. Typically, these markings point out the location of the cancer region in the image. Obviously, these films are not of use for DDSM unless the markings can be removed.

These problems are not major, and we have been able to adjust to them reasonably easily. In essence, the yield of usable cancer cases out of each year's cases is lower than originally anticipated. We can compensate for this by collecting cases from a broader time frame than originally anticipated. The main effect is that there is more "overhead" to the project than anticipated, due to the need to sift through more potential cases to get the same number of usable cases.
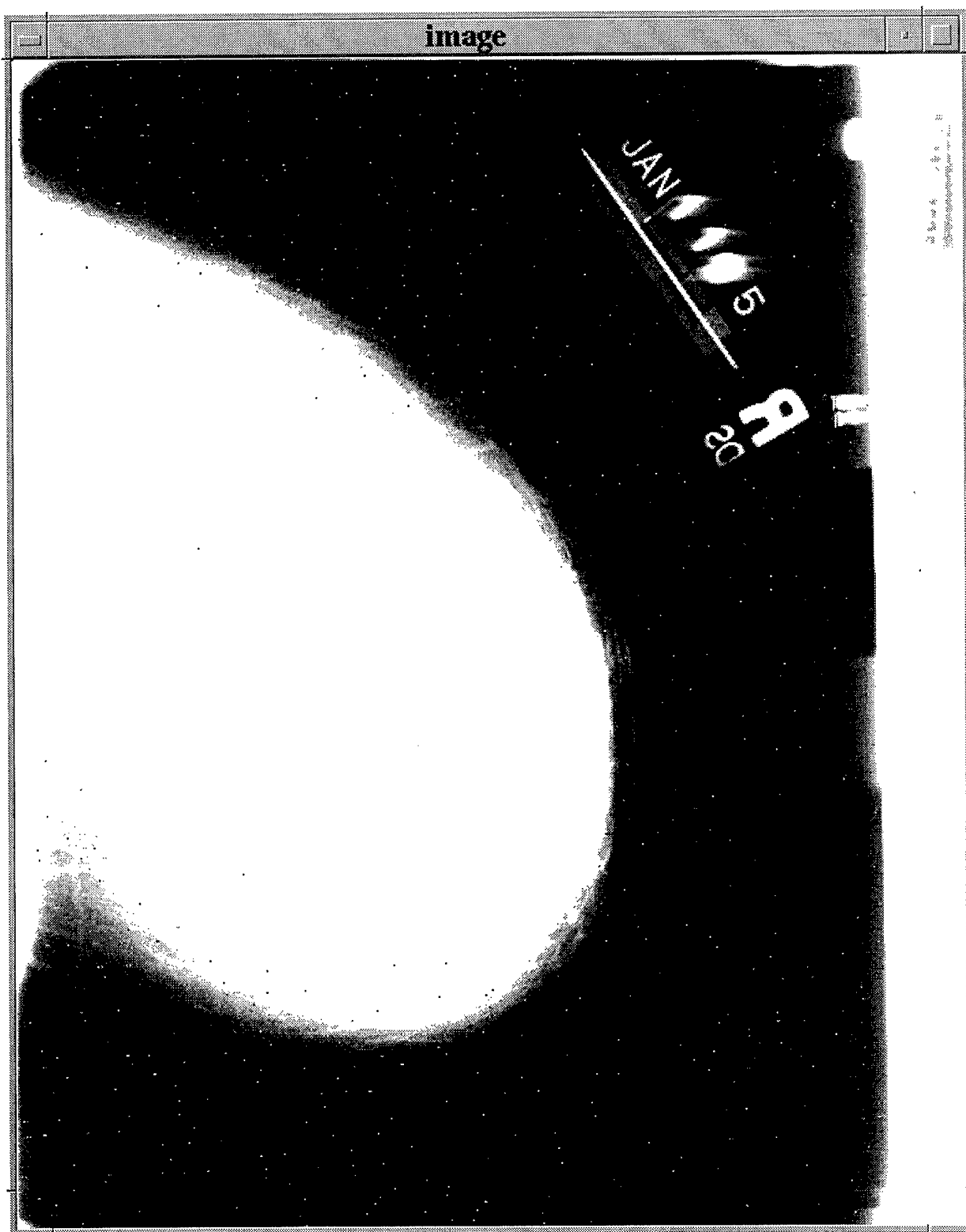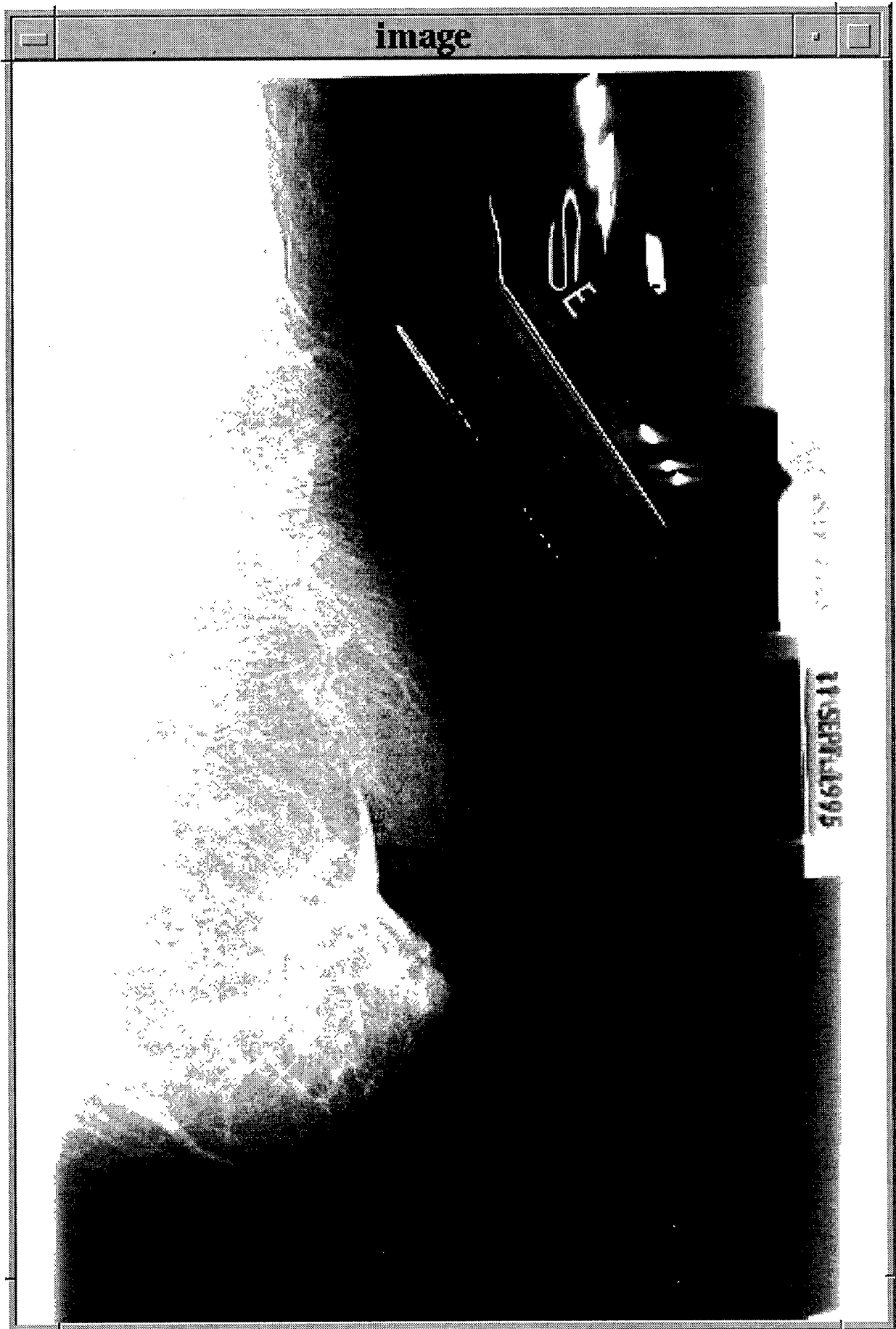
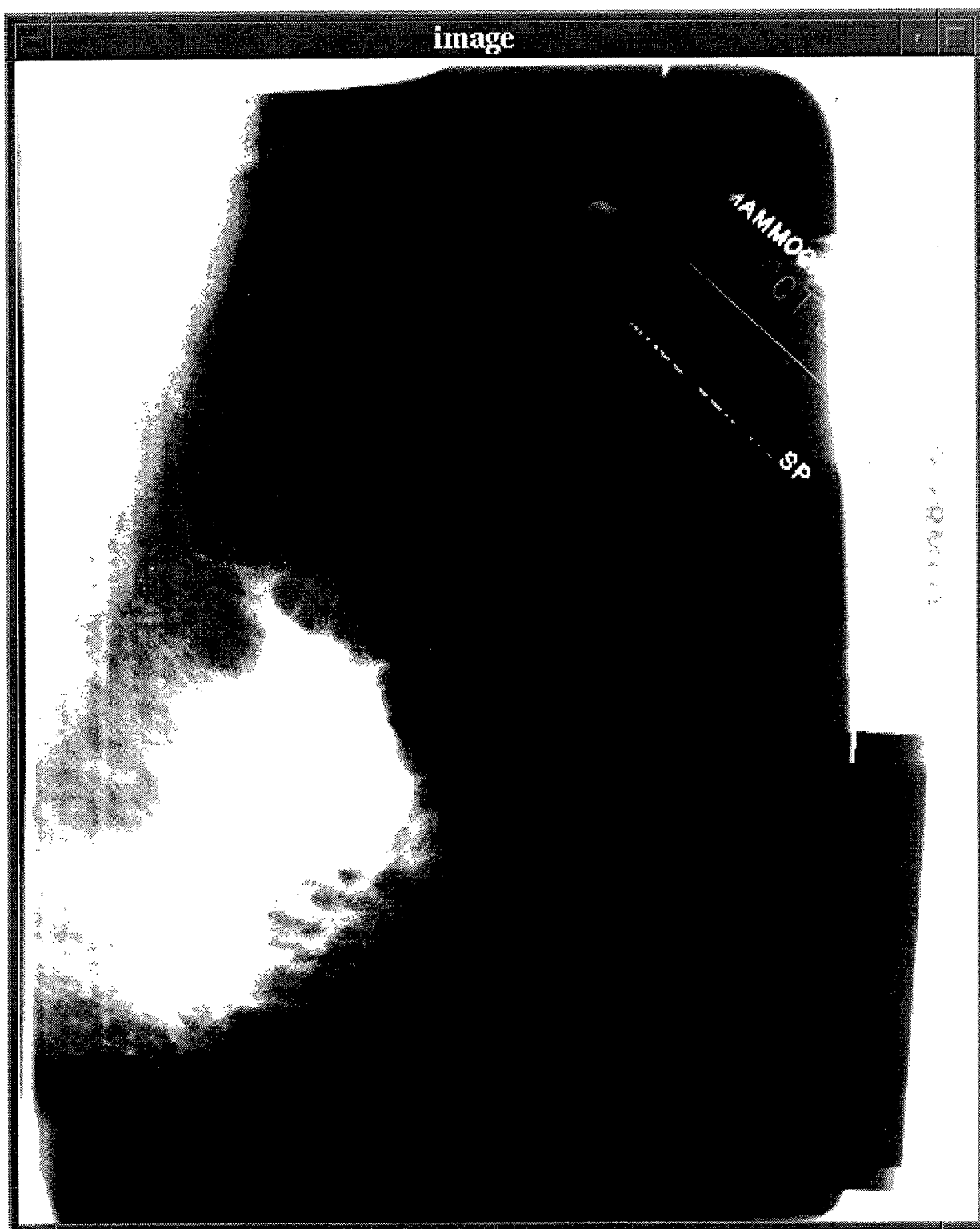Figure 1: Example image exhibiting the "speckles" artifact.

Figure 2

Figure 3: Example image exhibiting the "banding" artifact.

7 Plans for completion of the DDSM resource

We are now at the end of year three of what was originally scheduled to be a four-year project. We are clearly well behind the originally projected schedule. Our plans for completion of the DDSM resource are as follows.

Since the project cannot reasonably be completed in the next 12 months, we have requested the allowed one-year, no-cost extension to the grant period. This gives us approximately two years in which to complete the project. The goal is to accumulate an additional approximately 2,400 cases of data. To allow for completing the quality control checks and assembly of the data at USF, the data should be accumulated at the clinical sites over the next 18 or 19 months. Thus the goal is to achieve a data flow of approximately 130 cases per month over the next 18 months.

Fortunately, our expenditures and budgeting should allow the one-year, no-cost extension as a feasible option. Because we waited until after the data accumulation protocol for cancer cases had been fully worked out at MGH before beginning to bring in additional clinical sites, we did not spend the money budgeted for subcontracts as early as originally anticipated.

We are taking the following steps in order to achieve the necessary data flow.

First, we are investigating the possibility of replacing the DBA digitizer at MGH. We have had extensive discussions with the makers of the CobraScan digitizer about the requirements of our project. The have been working on a stack feeder which would have capacity suitable to our project. We are hopeful that they will have a demonstration system, with the stack feeder option, in the mammography unit at MGH in the near future.

Second, we have identified another clinical site. Dr. Suzanne Wooldridge is the radiologist in charge of mammography at Sacred Heart Women's Hospital in Pensacola, Florida. We have discussed the number and type of cases and associated data that would be needed in a subcontract collaboration. She has verified the technical and financial feasibility of the subcontract, and is enthusiastic about participating. We are currently working to finalize the details of this collaboration.

We can realize the required data flow by having approximately 30 cases from Bowman Gray, 30 cases from Sacred Heart, and 70 cases from MGH each month for the next 18 months. We will track the data flow from each site carefully over the next few months. If necessary, we will recruit an additional clinical site and/or shift the digitization work between sites.

8 Conclusions

Several volumes of images and associated data, along with software support tools, are already publicly available as a result of the DDSM project. The DDSM resource is currently being accessed by a variety of sites from around the world.

A number of problems have been encountered which have pushed the completion of the project behind schedule. This has necessitated that we take the allowed one-year no-cost extension to the grant period and re-plan the project. Through a combination or replacing the digitizer capability at MGH and adding new clinical sites to the project, we can still complete the original project goals on a new timetable.

A Extract of Access Log for May, June and July of 1997

The following is an abstract from the log of accesses made to the address made to the DDSM resource for the three-month period ending with this report submission. Only the first access from a given site in each month is listed. Often an individual site will generate a number of data transfers over a period of several days, sometimes repeated a few weeks later. It appears that some sites are not making their own "permanent" copy of the database, but transferring the data each time it is needed. The internet addresses in the log include a variety of military, commercial, government and educational institutions in the United States, as well as around the world.

Thu May 1 12:50:04 1997 102 l-ecn013.icaen.uiowa.edu ... -wychoi@icaen.uiowa.edu ftp 0 *
Thu May 1 17:43:08 1997 1 interlock.lexmark.com ... wwwuser@ ftp 0 *
Thu May 1 21:49:14 1997 1 202.30.108.83 ... nirvana@wh.myongji.ac.kr ftp 0 *
Mon May 5 09:21:28 1997 1 chrpa.ktt.vslib.cz ... mozilla@ ftp 0 *
Wed May 7 21:39:35 1997 13 proxy1.questnet.net.au ... squid_cache@questnet.net.au ftp 0 *
Thu May 8 01:07:20 1997 1 lux.sprc.qut.edu.au ... g.mcgarry@qut.edu.au ftp 0 *
Thu May 8 12:49:15 1997 8 ns1.littondsd.com ... mozilla@ ftp 0 *
Thu May 8 20:15:30 1997 1 dtm03-31.txdirect.net ... mozilla@ ftp 0 *
Fri May 9 06:47:20 1997 8 sauron.udg.es ... xcuf@songoku.udg.es ftp 0 *
Fri May 9 10:15:22 1997 63 love.tamu.edu ... guest@tamu.edu ftp 0 *
Fri May 9 13:58:09 1997 1 134.174.81.28 ... burgess@ulna.bwh.harvard.edu ftp 0 *
Sun May 11 16:01:59 1997 1 manwe.biophysics.mcw.edu ... rwcox@mcw.edu ftp 0 *
Tue May 13 14:41:48 1997 53 wingit.afit.af.mil ... mozilla@ ftp 0 *
Tue May 13 18:09:28 1997 13 dial11.interaxs.net ... mozilla@ ftp 0 *
Wed May 14 00:12:24 1997 1 congo.usc.edu ... mozilla@ ftp 0 *
Wed May 14 07:55:53 1997 40 criquet.snv.jussieu.fr ... mozilla@ ftp 0 *
Wed May 14 08:05:20 1997 1 pm3-02-215.port.shore.net ... mozilla@ ftp 0 *
Wed May 14 14:50:06 1997 1 internet80.camtronics.com ... turney@camtronics.com ftp 0 *
Thu May 15 00:43:40 1997 1 johnstone.ucr.edu ... mozilla@ ftp 0 *
Fri May 16 11:13:35 1997 1 worf-gw.calspan.com ... mambrett@calspan.com ftp 0 *
Mon May 26 07:30:26 1997 12 thor.roe.ac.uk ... ah@roe.ac.uk ftp 0 *
Mon May 26 22:18:21 1997 2 ad51-224.compuserve.com ... IE30User@ ftp 0 *
Tue May 27 00:32:22 1997 548 aci10.media.hokudai.ac.jp ... mozilla@ ftp 0 *
Tue May 27 19:45:43 1997 1 amethea.nsi.edu ... jon@nsi.edu ftp 0 *
Wed May 28 20:12:12 1997 1 phonebox2-9.vclass.uwf.edu ... mozilla@ ftp 0 *
Thu May 29 17:40:07 1997 12 148.202.30.79 ... mozilla@ ftp 0 *
Fri May 30 15:23:53 1997 1 cygnus.dss-online.de ... mozilla@ ftp 0 *
Fri May 30 17:30:59 1997 1 jjohnson.sarnoff.com ... mozilla@ ftp 0 *

Mon Jun 2 09:27:07 1997 1 ios.wcl2.ee.upatras.gr ... mozilla@ ftp 0 *
Tue Jun 3 07:51:15 1997 1 line2.riopreto.com.br ... lfernando@riopreto.com.br ftp 0 *
Tue Jun 3 08:44:59 1997 6 ilproxy.ans.net ... ilproxyuser@ilproxy.ans.net ftp 0 *
Wed Jun 4 07:39:19 1997 13 dalyan.ee.bilkent.edu.tr ... gurcan@ ftp 0 *
Wed Jun 4 14:58:10 1997 1 csc-14332.mgh.harvard.edu ... moorer@mgh.harvard.edu ftp 0 *
Thu Jun 5 07:49:39 1997 21 msia02.msi.se ... mozilla@ ftp 0 *

Thu Jun 5 09:09:28 1997 40 babbar.stsci.edu ... nieto@stsci.edu ftp 0 *
Thu Jun 5 12:12:07 1997 1 destroyer.cs.uwf.edu ... sutton@csee.usf.edu ftp 0 *
Sat Jun 7 10:16:37 1997 1 image.cityu.edu.hk ... 00410987@cpccux0.cityu.edu.hk ftp 0 *
Sat Jun 7 23:56:57 1997 1 eassun.eas.gu.edu.au ... brijesh@eassun.eas.gu.edu.au ftp 0 *
Tue Jun 10 03:13:57 1997 1 withnail.ee.wits.ac.za ... guest@ ftp 0 *
Tue Jun 10 13:28:40 1997 28 osiris.sarnoff.com ... jjohnson@sarnoff.com ftp 0 *
Wed Jun 11 03:33:42 1997 1 user252.s147.samsung.co.kr ... dongwoo@saitgw.sait.samsung.co.kr ftp 0
*
Wed Jun 11 09:22:42 1997 1 130.181.35.120 ... mozilla@ ftp 0 *
Wed Jun 11 20:14:26 1997 62 sfo-ca5-10.ix.netcom.com ... mozilla@ ftp 0 *
Thu Jun 12 02:05:20 1997 1 pattern-gw.ece.arizona.edu ... lbaig@ ftp 0 *
Thu Jun 12 07:26:23 1997 1 169-98-46.ipt.aol.com ... user@somehost.com ftp 0 *
Thu Jun 12 12:49:15 1997 1 192.88.11.10 ... mozilla@ ftp 0 *
Thu Jun 12 15:48:52 1997 22 albert.space.honeywell.com ... mozilla@ ftp 0 *
Fri Jun 13 06:22:38 1997 1160 rub126.mi00.mi.interbusiness.it ... spaghetti@synapsis.it ftp 0 *
Sun Jun 15 05:46:05 1997 1 msn-53.bn.eunet.de ... bieling@uni-bonn.de ftp 0 *
Mon Jun 16 09:59:02 1997 18 200.137.130.201 ... mozilla@ ftp 0 *
Mon Jun 16 21:16:54 1997 4 ppp-148.hamilton-03.ican.net ... mozilla@ ftp 0 *
Thu Jun 19 17:46:52 1997 31 spin.beckman.uiuc.edu ... mozilla@ ftp 0 *
Thu Jun 19 22:17:30 1997 1 s04-pm01.clemson.campus.mci.net ... whoever@microsoft.com ftp 0 *
Fri Jun 20 05:56:19 1997 15 ios.wcl2.ee.upatras.gr ... mozilla@ ftp 0 *
Sat Jun 21 06:29:35 1997 1 breda17.pstn03.concepts.nl ... IE30User@ ftp 0 *
Sat Jun 21 16:40:25 1997 2 194.91.193.227 ... mozilla@ ftp 0 *
Fri Jun 27 13:29:17 1997 1 tsargent.dba-sys.com ... mozilla@ ftp 0 *
Sun Jun 29 19:00:30 1997 5 202.197.14.46 ... rswang@csit.edu.cn ftp 0 *

Tue Jul 1 02:58:26 1997 1 mate67.ellensburg.com ... nate@ellensburg.com ftp 0 *
Tue Jul 1 07:20:34 1997 4936 137.204.230.24 ... marengo@fisica.dsnet.it ftp 0 *
Wed Jul 2 15:54:50 1997 1 max.cs.niu.edu ... z914206@niu.edu ftp 0 *
Wed Jul 2 16:12:09 1997 3 nijmegen-015.std.pop.tip.nl ... IE30User@ ftp 0 *
Thu Jul 3 09:42:46 1997 1584 image.cityu.edu.hk ... 00410987@ ftp 0 *
Fri Jul 4 08:55:48 1997 13 200-82-50.ipt.aol.com ... user@somehost.com ftp 0 *
Tue Jul 8 04:12:19 1997 1 zen.maths.uts.edu.au ... hung@zen.maths.uts.edu.au ftp 0 *
Mon Jul 14 09:35:27 1997 1 sp20.sp2.cineca.it ... squid@proxy.cineca.it ftp 0 *
Mon Jul 14 09:40:54 1997 1 egoli.uni.net.za ... cache@uni.net.za ftp 0 *
Mon Jul 14 10:14:13 1997 442 commsrv3.ee.wits.ac.za ... pfistere@odie.ee.wits.ac.za ftp 0 *
Thu Jul 17 08:14:48 1997 1 192.165.125.2 ... httpgw@ ftp 0 *
Thu Jul 17 09:20:53 1997 13 200.20.10.215 ... mozilla@ ftp 0 *
Fri Jul 18 05:21:31 1997 755 i0313p133.universal.nl ... IE30User@ ftp 0 *
Fri Jul 18 18:29:51 1997 55 hsr.edrd.dnd.ca ... mozilla@ ftp 0 *
Fri Jul 18 22:04:52 1997 19 mail.chollian.net ... stlee@mer.ti.hangkjong.ac.kr ftp 0 *
Sun Jul 20 04:03:38 1997 1 bd51-0.Breda.NL.net .. IE30User@ ftp 0 *
Mon Jul 21 17:43:15 1997 1 jones.ucr.edu ... mozilla@ ftp 0 *
Mon Jul 21 18:40:57 1997 1 destroyer.cs.uwf.edu ... mozilla@ ftp 0 *
Tue Jul 22 03:20:12 1997 1 gemsgw.med.ge.com ... ns-proxy@gemsgw.med.ge.com ftp 0 *
Tue Jul 22 12:04:41 1997 13 143.225.233.100 ... mozilla@ ftp 0 *

Tue Jul 22 22:43:50 1997 1 192.245.251.221 ... kimin@bulldog.hallym.ac.kr ftp 0 *
Thu Jul 24 11:58:15 1997 1 khan.dc.aaec.com ... skadambe@dc.aaec.com ftp 0 *
Thu Jul 24 21:53:09 1997 1 1Cust96.max28.philadelphia.pa.ms.uu.net ... IE30User@ ftp 0 *
Fri Jul 25 03:41:41 1997 48 bsd0.mds.qmw.ac.uk ... http-gw@bsd0.mds.qmw.ac.uk ftp 0 *
Fri Jul 25 11:17:21 1997 1 dali.telebyte.nl ... squid@ ftp 0 *
Fri Jul 25 12:51:02 1997 6 kit.cis.ohio-state.edu ... mozilla@ ftp 0 *
Fri Jul 25 23:23:00 1997 1 kato-ip-97.theramp.net ... mozilla@ ftp 0 *
Sat Jul 26 13:04:10 1997 1 NISYROS.med.upatras.gr ... mozilla@ ftp 0 *
Mon Jul 28 16:14:00 1997 1 Jeopardy.games.GlobalXS.nl ... IE30User@ ftp 0 *